

# ACTIVITY REPORT

January 2002



**Natural  
Gas &  
Oil  
Technology  
Partnership**

bringing department of energy national laboratories capabilities to the petroleum industry

Los Alamos  
Los Alamos, NM 87545  
(505) 667-7811

Sandia  
Albuquerque, NM 87185  
(505) 844-7333

Lawrence Livermore  
Livermore, CA 94551  
(925) 422-5196

Lawrence Berkeley  
Berkeley, CA 94720  
(510) 486-5085

Argonne  
Argonne, IL 60439  
(202) 488-2415

Brookhaven  
Upton, NY 11973  
(516) 344-3819

Idaho  
Idaho Falls, ID 83415  
(208) 526-7004

Oak Ridge  
Oak Ridge, TN 37831  
(865) 574-4977

Pacific Northwest  
Richland, WA 99352  
(509) 372-4565

To: William F. Lawson, Director  
National Petroleum Technology Office  
U.S. Department of Energy  
P.O. Box 3628  
Tulsa, OK 74101

From: J. Albright, Los Alamos  
D.J. Borns, Sandia  
J. Ziagos, Lawrence Livermore  
G.M. Hoversten, Lawrence Berkeley  
D. Schmalzer, Argonne  
A. Goland, Brookhaven  
B. Reynolds, Idaho  
T. Schmidt, Oak Ridge  
B. Saffell, Pacific Northwest

cy: G. Dehoratiis, DOE Fossil Energy  
E. Allison, DOE Fossil Energy  
L. Capitanio, DOE Fossil Energy  
A. Hartstein, DOE Fossil Energy  
B. Hochheiser, DOE Fossil Energy  
E. Subia-Melchert, DOE Fossil Energy  
N.B. Woodward, DOE Office of Science  
D. Alleman, DOE-NPTO-Tulsa  
J. Casteel, DOE-NPTO-Tulsa  
N. Comstock, DOE-NPTO-Tulsa  
B. Lemmon, DOE-NPTO-Tulsa  
R. Lindsey, DOE-NPTO-Tulsa  
R. Long, DOE-NPTO-Tulsa  
K. Sterling, DOE-NPTO-Tulsa  
D. Sutterfield, DOE-NPTO-Tulsa  
J. Ammer, NETL  
F. Brown, NETL  
H. Guthrie, NETL  
B. Gwilliam, NETL  
J. Rogers, NETL  
B. Tomer, NETL  
F. Toro, NETL  
A. Yost, NETL

Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

**January, March, May, July, September, November**  
Oil and Gas Recovery Technology  
Drilling, Completion, and Stimulation Technology  
Diagnostic and Imaging Technology

**February, April, June, August, October, December**  
Upstream Environmental Technology  
Downstream Environmental Technology  
Ultra-Clean Fuels Technology

**Natural Gas and Oil Technology Partnership on the World Wide Web: <http://www.sandia.gov/ngotp/>**

## Oil and Gas Recovery Technology

### Improved Waterflooding Through Control of Brine Composition and Other Factors

(BP Amoco, U of Wyoming, and INEEL)

Work continues on the Monument Butte field cores from the Uintah Basin, UT. Field cores were collected and are being prepared for waterflooding tests at the INEEL and University of Wyoming. Waterfloods will be done at the reservoir temperature of 140°F. The pour point of this high-wax crude oil is about 95°F.

Initial results from the INEEL using Berea sandstone, Monument Butte field core, and simulated reservoir and injection brine are promising. Injecting fresh water recovered more oil than when reservoir brine was used as the sweeping fluid. The fresh-water flood recovered 6.2% more oil than the reservoir-brine flood.

Preparation of the field cores continues. The INEEL is preparing three pairs of reservoir core plugs for experimental study. The permeability of the three pairs is 6 md, 3 md, and 30 md. One core of each of the pairs will be flooded with reservoir brine and the other will be flooded with fresh water.

The University of Wyoming commenced work on three different waterfloods on each of three core plugs with permeabilities of 10 md, 6 md and 2.5 md.

Waterfloods:

- connate brine = reservoir brine  
driving brine = reservoir brine
- connate brine = reservoir brine  
driving brine = fresh injection water
- connate brine = driving brine = fresh injection water

### Fluid Identification Acoustic Logging Tool

(BP Amoco, CGG, ChevronTexaco, Conoco, Landmark Graphics, Mobil, Schlumberger, Shell, Smedvig Unocal, Ward Petroleum, Western Atlas, and LANL)

#### Highlight:

- Simpler approach to determining gas/liquid volume fraction identified.

Project researchers recently identified a simpler approach to determining the gas/liquid volume fraction in borehole flow streams. This approach does not require an additional sensor for determining the gas-liquid volume fraction, but takes advantage of the same piezoelectric resonator with some modifications of the electrode arrangement. Researchers are now investigating this approach and developing the theoretical model for it.

Laboratory experiments show that it is possible to determine both gas volume and multiphase flow rate, in addition to monitoring the fluid composition. Researchers are now in the process of designing simple electronic circuitry to implement these new features. Once this is accomplished, the acoustic logging tool will be more versatile.

### Measuring Sucker Rod Pump Parameters Downhole (Harbison-Fischer, UT-Austin, and SNL)

#### Highlight:

- Prototype downhole compression chamber pressure transducer received.

The first downhole compression chamber pressure transducer arrived, and project researchers are fabricating the hardware to install the transducer on the outside of the sucker rod pump tubing.

High-speed signals have been acquired without aliasing requires filtering. When the instrumented sucker rod was first installed at the University of Texas (UT), a bug in the data-acquisition card drivers prevented the proper implementing of filtering. The drivers were upgraded and progress is being made on fixing the problem. This should improve the correlation between load changes and compression chamber when the valves open and close.

**Formation Logging Tools for Microboreholes**

(DeepLook, ChevronTexaco, and LANL)

**Highlight:**

- First directional survey of microhole completed.

The data from the deviation survey of the microhole at the San Ysidro, NM, site was processed to determine the trajectory of the borehole. The survey provided good repeatability between the run-in and pull-out surveys and a maximum inclination of  $4.5^\circ$  was measured at 326 ft; a maximum dogleg of  $16^\circ$  per 100-ft at a depth of 240 ft was calculated with 10-ft averaged values from the survey. The well trajectory was calculated in 10-ft increments using five published calculation methods and smoothing techniques, and the calculated maximum dogleg for each calculated trajectory ranged between  $0.17^\circ$ - $0.34^\circ$  per 100 ft, at a depth of 250 ft.

**Coupled Geomechanical Deformation, Fluid Flow, and Seismic Modeling**

(Mobil, Schlumberger, UT-Austin, and SNL)

**Highlight:**

- Modifications made to JAS3D to read initial porosity and permeability state from IPARS flow simulator.

Modifications were made to JAS3D to read the initial porosity and permeability state from the IPARS flow simulator. This modification will provide the potential for spatially varying porosity and permeability fields to be treated in JAS3D without duplicating information already available in IPARS. In addition, this modification will allow the coupled IPARS/JAS3D code to model more realistic field problems.

Work continues on the development of an automatic time-stepping algorithm for determining the frequency of communication between the flow simulator and the geomechanics code. The version of JAS3D used for the coupling with IPARS is undergoing an upgrade to the latest version, which is written in FORTRAN 90.

**Semiautomatic System for Waterflood Surveillance**

(ChevronTexaco, Case Services, and LBNL)

No report received.

**Mechanisms of Oil Recovery and Validation of Corefloods**

(ChevronTexaco, Phillips, and LBNL)

**Highlights:**

- Single pore calculations performed.
- Depositional model developed.

The capillary entry pressures, hydraulic conductances, phase volumes, and saturations of a single angular capillary tube filled with three immiscible fluids were calculated. The calculations were performed for arbitrary corner and contact angles and surface tension coefficients. These calculations for a single pore are the first steps in the development of a predictive model of three-phase flow in mixed-wet media represented by a pore-network.

The code NetSimCPP was used to study the anisotropy of the pore network by simulation of flow in different directions.

**Pore network generation**

Based on the understanding of rock-forming processes, such as sedimentation, compaction, and diagenesis, project researchers developed a depositional model to simulate these processes and reconstruct some particular porous rocks. The necessary input data for the depositional model include grain size distribution, porosity, and the type and amount of cement materials. The depositional model will be used to further study the mechanical and transport properties of rock and to generate synthetic 3D images for pore network generation.

The work on extracting pore networks from 3D rock images has begun.

**Direct Simulation of Near-Wellbore Mechanics**

(ChevronTexaco, Halliburton, Schlumberger Shell, MIT, NMT, and SNL)

**Highlight:**

- The 2D code was parallelized and optimized for shared-memory machines.

Negotiations with Schlumberger were successfully concluded during this project period. Schlumberger will be joining the project cooperative research and development agreement (CRADA), resulting in an additional \$60K funds-in and \$45K in-kind support over the next two years. This agreement was approved by the DOE and is now awaiting execution by the industry participants.

Another research collaboration was initiated with the geohydrology group at New Mexico Tech. This collaboration, which will be formalized later this year through a licensing agreement for our software, leverages New Mexico Tech's extensive research expertise in the fundamental physics underlying the application problems of interest. New Mexico Tech will initially beta-test and later apply the project codes to study fluid-induced fracture initiation.

The 2D code was parallelized and optimized for shared-memory machines. Initial tests of this parallelized version suggest excellent speedup. Current work is focused on the continued development of this parallel code and the prototyping of the 3D code.

The publication, "Discrete Element Modeling Applied to Laboratory Simulation of Near-Wellbore Mechanics," by Cook et al was accepted for publication in the *International Journal of Geomechanics*.

"Simulation of Borehole Failure Phenomena Using Discrete Element Modeling," by Lee, M.Y., B. K. Cook, A.A. DiGiovanni, E.D. Perkins, and J.R. Williams, was published in *Eos Trans. AGU*, 82(47), T51A-0846, 2001.

**Well Integrity Assurance for Sub-Salt and Near-Salt Deepwater GoM Reservoirs**

(BHP, BP Amoco, ChevronTexaco, Conoco, ExxonMobil, Halliburton, Kerr-McGee, Phillips, Shell, and SNL)

A summary, or primer, of salt mechanics issues relevant to the development of deepwater Gulf of Mexico (GoM) sub-salt and near-salt fields was prepared. The primer includes an overview of salt mechanics, a summary of constitutive models for Gulf Coast domal salts and Waste Isolation Pilot Project salt, a summary of the possible controls on the salt creep rate, a bounding steady-state strain rate contour map calculated for salt in deepwater GoM conditions (in the absence of geometrical and structural constraints), and a discussion about geometrical constraint in the field settings of interest.

As part of their in-kind contribution, BP Amoco released results of laboratory creep tests performed on rotary sidewall cores taken from a salt body adjacent to the Mad Dog field. SNL performed analyses of the data, including a comparison with the existing salt model database. Forward predictions using the Bayou Choctaw salt model were provided to guide additional laboratory tests.

A major effort was initiated focusing on finite element modeling of well casings. The analyses include initial transient creep behavior following excavation (drilling) and subsequent closure behavior over a 20-30 year service lifetime. Initial analyses considered different casing sizes, stress, and temperature conditions. In addition, loading for a cemented versus uncemented annulus and potentially non-uniform loading as a result of hole quality (i.e., perfectly circular versus slightly elliptical boreholes) were assessed.

A translator to port analyses from the EXODUSII database format used in the SNL finite element codes into General Mesh Viewer (GMV), a public domain highly flexible 3D visualization software package developed at LANL, was developed.

J.T. Fredrich was an invited speaker at the International Workshop "Geomechanics in Reservoir Simulation" which convened at the Institut Français du

Pétrole in Rueil-Malmaison, France, December 5-7, 2001.

A manuscript was submitted to *Oil & Gas Science and Technology - La Revue de l'IFP*, January 2002, entitled, "Large-Scale Three-Dimensional Geomechanical Modeling of Reservoirs: Examples from California and the Deep-water Gulf of Mexico," by J. T. Fredrich and A. F. Fossum.

## Drilling, Completion, and Stimulation Technology

### Coiled Tubing Marking and Mark Recognition

(Quality Tubing and INEEL)

The final report was prepared and submitted for review. The review process is expected to be complete in the first week of March 2002.

### Drill Cuttings Injection Field Experiment

(BP Amoco, ChevronTexaco, Exxon, Gas Research Institute (GRI), Halliburton Energy Services, Hughes Christensen, MSD, Pinnacle Technologies, Schlumberger, Shell, and SNL)

No report received.

### 3D Analysis for Induction Logging in Horizontal Wells

(BP Amoco, ChevronTexaco, Conoco, Electromagnetic Instruments, Exxon, Halliburton, Mobil, Phillips, Schlumberger-Doll, Shell, Unocal, Western Atlas, and SNL)

#### Highlight:

- Validation of the LIN preconditioner is complete.

Project researchers are in the final stages of completing a licensing agreement with a service company for the 3D anisotropy modeling software.

One of the publications arising from this project resulted in a cover illustration for the Nov/Dec special issue of *Petrophysics*, devoted to anisotropy.

Validation of the low-induction number (LIN) preconditioner is complete. Typical results indicate that the LIN reduces the time needed to compute one 3D forward solution by a factor of five. A draft of a manuscript describing these results is now complete and will be submitted to *Geophysics* in the coming weeks.

### Downhole Seismic Source for Look-Ahead Pore Pressure Prediction While Drilling

(ChevronTexaco, INEEL, and LBNL)

#### Highlight:

- Test results presented at NGOTP meeting in Houston, TX.

INEEL designed and built a four-channel, 800-J, capacitive discharge seismic source (sparker) last fall. It is contained in an 8-ft 250-lb section of 5.5-in diameter pipe, complete with a mud-low path intended for implementation in a downhole drill string. In addition, a second previously constructed wire line deployed source based on the electrical disassociation of water into a combustible mixture of gaseous hydrogen and oxygen was modified to increase its acoustic output.

Both sources were shipped to Seneca Lake, NY and tested at the Naval Undersea Warfare Center. They were both wire-line deployed off the side of a floating platform adjacent to a 24-channel hydrophone array up to depths exceeding 400 ft. Hundreds of shots were recorded on a standard seismic recorder. The sparker produced short duration impulse-like source functions. The combustible source produced a longer duration decaying sinusoidal signal.

Results were presented at the November 2001 NGOTP meeting in Houston, TX. Future FY02 testing includes high-pressure (greater than 4500 psi) laboratory tests to evaluate sparker performance at depth and wire line deployed downhole testing.

**Acoustic Telemetry (MWD)**

(ABB, Electroacoustics Research Laboratory, Extreme, and SNL)

**Highlight:**

- Additional field tests of acoustic telemetry tool performed.

As a follow-up to the successful drilling test of the acoustic telemetry tool, project researchers field tested it in three additional applications. Two of these tests were river crossing drilling projects. The third was a gas well drill stem test (DST) application.

In one of the river crossing projects, researchers attempted to transmit the telemetry signal through a 700-m horizontal well containing a 3000-lb hole opener. This combination stopped the telemetry signal. However, in the other 500-m river crossing project, as well as in the DST, researchers obtained and decoded the telemetry signals. Moreover, in the DST application, project researchers transmitted the telemetry signal through both the DST tool and a shock sub. In this case, the tool was used for real-time monitoring of the flow and shut-in pressure in a packed off production zone.

**Development of Chemically Bonded Ceramic Borehole Sealants**

(GPRI, ANL, and LANL)

**Highlights:**

- Researchers measure setting time on different formulations of Ceramicrete.
- Static tests begun.

Researchers continue to measure the setting time on different formulations of Ceramicrete. In addition, researchers also started static tests, in which the samples taken out of consistometer are maintained at static well temperatures under water to test if they set well. It was found that although the 3-5 hr setting time up to 300 °F was met, these formulations need some adjustment to ensure hardening within a short time.

Previous testing indicated that setting time depends on the type of ash used. Adjusting the content and type of ash provides consistent results on pumping times between 3-5.5 hrs in the temperature range of 80-300 °F and in the pressure range of 700-16650 psi.

The effect of compositional variations on thickening time was studied. Project researchers progress towards static temperature tests, in which slurries are kept under water at the static temperatures of the well and tested for hardening. At present, the formulations are being adjusted to provide rapid setting after pumping at downhole static temperatures.

Project researchers plan to take these formulations to Chevron's Cement laboratory and get the data validated by Chevron experts.

**Coiled-Tubing Deployed Microdrilling with Real-Time, Downhole Monitoring**

(DeepLook, Phillips, and LANL)

**Highlight:**

- Plan for improving the mud cleaning system developed.

Project researchers attribute the very high maintenance cost for the high-pressure mud pump to the poor cleaning performance of the off-the-shelf mud cleaning system. A consultant, an equipment fabricator, and a mud product supplier assisted researchers in developing a plan to improve the mud cleaning system. The three-part plan follows:

1. Modify the feed pump for the hydrocyclone desanders in order to increase the output of the pump and fluid velocity through the hydrocyclones.
2. Substitute low molecular weight polymer for the bentonite and polymer mud used in previous drilling demonstrations.
3. Replace the orbital shale shaker with a linear shaker if the first two actions are not successful in reducing pump maintenance costs by 75%.

**Microdrilling, Completion, and Production Demonstrations**

A tentative plan to drill and complete a 600-ft deep hole at Fenton Hill was explored. Project researchers are also investigating the possibility of producing water from the aquifer as a microhole production demonstration.

Project researchers discussed the possibility of conducting a microdrilling

demonstration at Teapot Dome with Rocky Mountain Oilfield Technology Center (RMOTC) staff. The researchers plan to drill, complete, and produce several 600-ft deep Shannon oil wells using the Los Alamos coiled-tubing drill rig.

### Effects of Well Conditions on Post-Perforation Permeability

(Halliburton,  
Penn State, and LLNL)

#### Highlight:

- Experimental particle-size distribution measurements interpreted.

The simulation capability depends upon detailed experimental data to provide model parameters. In addition to the previously measured permeability maps of several cores tested under different under-balances, particle-size distributions were measured along the length of the cores. These particle-size data are being interpreted to allow a quantitative comparison of the experimental and simulation results.

Preliminary results indicate that the migration of fines predicted by the model is qualitatively similar to the experimental results. Ongoing analysis of the particle-size data will provide improved estimates of input parameters and improved direct comparisons of simulations and experiments.

### Lifetime Performance Monitoring of Synthetic Fiber Mooring Ropes

(Petroleum Composites, Puget Sound Rope, Shell  
International Exploration and Production,  
Whitehill Manufacturing, and ORNL)

#### Highlight:

- Bench-scale tests of optical fiber strain measurements complete.

The project goal is to develop and demonstrate a reliable and robust method for monitoring strain in braided and twisted strand Synthetic Fiber Mooring Ropes (SFMR), with the ultimate objective of deploying a strain monitoring system on SFMR anchoring deep-water platforms in the Gulf of Mexico. The evaluation of available polymeric optical fibers in bench-scale tests is substantially complete. All fibers tested met the strain measurement requirements, and one fiber was downselected for integration into rope segments. The next task will be to test the ability of fiber to measure rope strains in tensile testing.

### Disposable Fiber Optic Telemetry System for Use With Coiled Tubing

(GTI, CTES,  
and SNL)

#### Highlight:

- Prototype fiber injector completed.

A design was prepared and reviewed for the prototype fiber injector which addresses the challenge of adapting technology developed by CTES for injection of heavy electrical cables to handling the much smaller and more delicate optical fibers. The design uses the capstan-based injection system pioneered by CTES, modified to accommodate the sub-millimeter-diameter optical fiber. The injector design shows some of the advantages of using bare optical fiber. It is much smaller, 1 ft versus several feet in diameter for a cable injector. The reduction in size should greatly reduce cost and operational difficulties.

Manufacturing of the injector was completed January 2002. The unit was satisfactorily assembled, and a method is being developed for installing the fiber into the injector. The stiffness of the fiber is, as anticipated, complicating this step.

**Automatic Flaw Detection and Identification for Coiled Tubing**

(U of Tulsa, INEEL)

University of Tulsa (U of TULSA) and INEEL personnel met at the U of Tulsa to discuss the interaction between INEEL's automatic flaw detection and identification for coiled-tubing and U of Tulsa's Industrial Consortium coiled-tubing research projects. Initial program commitments and integration between the two programs were discussed. The U of Tulsa's laboratory equipment was reviewed and enhancement recommendations were made to ensure that the equipment and subsequent data collected by the equipment could be integrated and used by the INEEL project. INEEL and U of Tulsa collaboration with respect to the laboratory equipment design, manufacture, and data acquisition were also discussed.

## Diagnostic and Imaging Technology

**Advanced Sensor Technology for Microborehole and Other Seismic Instrumentation**

(Input/Output, Philips, and LANL)

**Highlight:**

- Line seismic data collected with the multilevel array.

The four-level, three-component MEMS seismic array was deployed and data was acquired in the microhole at the San Ysidro, NM, site. The objectives of the test were to (1) see if anticipated improvements to the system were realized, and (2) demonstrate the integration of the microhole system into a commercial seismic-line data-acquisition system. Line seismic data was collected using a Bison accelerated weight drop as a source. Data was acquired with a 24-bit, 48-channel OYO-DAS-1 data acquisition system. Initial examination of the data showed an improved performance of the system. Data is currently being processed and analyzed.

**Large Downhole Seismic Sensor Arrays**

(ChevronTexaco, Conoco, Exxon, OYO Geospace, Shell, U of Arkansas, and INEEL)

**Highlight:**

- Final report completed.

The final report is complete and is available from INEEL.

The prototype clamping systems tested demonstrate possible solutions for developing a large downhole seismic sensor array. Further development can improve their overall performance.

The first attempt at meeting design objectives, permanent magnet clamping, is a passive, reliable, and moderately successful option. Magnets are inexpensive, and single geophone elements can be economical, so mounting one geophone per 20-lb-force magnet would be very affordable. If such elements were configured, the module design only needs to reliably place the magnet/geophones against the casing for sliding contact, and to provide connections and housing for the electronics. Such a configuration could have one amplifier module and/or analog to digital converter for multiple modules. Some of these concepts were tried, and their performance was not reliable. Nevertheless, adequate performance was exhibited, although infrequently. Due to the magnet clamp's uncompromising simplicity and low cost, it should not be rejected from consideration.

**Integration Issues**

The prototype tests were of single modules. Development of a commercial system consisting of many sondes will require additional infrastructure and perhaps architecture changes. A system of passive, well clamped, robust sondes would most easily be developed into a large array-more complex systems may

produce better results when tested as a single unit but may not as easily be integrated into a reliable large array. A complex system, such as the INEEL's down-hole pump, must include additional features when incorporated into a larger instrument string.

### **Coiled Tubing**

Clamping coiled tubing requires devices on the outside of the tubing to be attached as the tubing is deployed. Passive clamps, such as magnets, are not likely to offer sufficient force. The power to operate an active clamp must come from either within the tubing or from co-deployed umbilicals. In either case, there will be concerns regarding draining and differential head pressure; however, because CT can offer larger flow pathways, some problems may be mitigated. Nevertheless, the most likely solution would be pneumatics with pressure-control devices, because hydraulics would still impose static head pressures, under certain conditions, that the system could not accommodate.

### **Recommendations**

Near the end project, INEEL engineers briefly investigated the possibility of "nonclamping" sondes. Two test apparatuses were built; one was configured as a prototype and tested against the fixed geophones, and the other was bench-tested to demonstrate function. Both devices demonstrated promise, but because these concepts were a departure from the project's scope they were not pursued. Due to their greater simplicity, these concepts should be explored further.

## **Improved Prestack Kirchhoff Migration for Complex Structures** (Conoco, Cray/SGI, Golden Geophysical, Kerr-McGee, Shell, and LANL)

No work was scheduled for this reporting period.

## **Testing Advanced Computational Tools for 3D Seismic Analysis Using the SEG/EAGE Model Dataset** (Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, Burlington Resources, ChevronTexaco, Conoco, Edison Chouest Offshore, Exxon-Mobile, GECO-Prakla, Golden Geophysical, Kerr-McGee, Marathon, Mitchell Energy, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Union Pacific Resources, Unocal, Western Geophysical, Stanford, UC-Davis, U of Houston, LANL, LLNL, and ORNL)

### **Highlight:**

The project is complete; no additional funding is expected.

- Project completed.

## **Integrated Reservoir Monitoring Using Seismic and Crosswell Electromagnetics** (ChevronTexaco, Electromagnetic Instruments, TomoSeis, LBNL, and SNL)

The project is in close-out phase, and a manuscript is being prepared. Monthly reports will no longer be filed.

**Frequency-Dependent Seismic Attributes of Fluids in Poorly Consolidated Sands**

(Baker-Atlas, ChevronTexaco, TomoSeis, Vastar, and LBNL)

The project is in close-out phase, and a manuscript is being prepared. Monthly reports will no longer be filed.

**Inversion of Full Waveform Seismic Data for 3D Elastic Parameters**

(Amerada Hess, ChevronTexaco, Conoco Fairfield Industries, GX Technology, Marathon, Unocal, and SNL)

**Highlight:**

- Two poster presentations delivered at the American Geophysical Union meeting.

Two poster presentations on the full waveform seismic inversion approach were delivered at the annual meeting of the American Geophysical Union in San Francisco, CA, in December 2001. One poster illustrated a successful (synthetic) application of the nonlinear inversion algorithm in locating a deeply buried low-velocity anomaly within a 3D elastic earth model representing the Puget Sound Region of Washington. A distribution of subsurface earthquake sources provided the illuminating seismic radiation, and three-component particle displacement seismograms were recorded at a sparse set of surface receivers. The other poster examined three alternative methods for computing the elastic wavefield sensitivities required in the full waveform inversion procedure. The study concluded that the approach presently utilized in the algorithm, based on the seismic reciprocity principle, is the most computationally efficient method for large numbers of subsurface inversion gridpoints.

Testing and analysis of the 3D nonlinear inversion algorithm continues. In particular, an amplitude scaling ambiguity was recently resolved in the solution of the large and sparse set of linear algebraic equations for the model perturbation vector. Resolution of this problem eliminates the need for a computationally demanding line search within the model space to determine the precise magnitude of the model update vector. Testing of the inversion approach with multiple point diffractor models illustrated the ability to successfully locate point scatterers in space, and resolve different elastic parameter types (i.e., elastic moduli and mass density).

A redefinition of project tasks is currently under way, in light of the dramatically reduced funding allocated to this project for the coming fiscal year. Much commentary at the recent NGOTP-DIT review meeting correctly noted the “ambitious” and computationally “aggressive” nature of this research and development project.

However, project researchers are attempting to adapt the 3D full waveform elastic inversion methodology to more practical seismic exploration issues.

**High-Speed 3D Hybrid Elastic Seismic Modeling**

(Burlington Resources, GX Technology, and LBNL)

Project researchers concluded the project because the final stage was not funded. The Message Passing Interface (MPI) standard-based C++ framework Wave, which takes care of parallelization of FORTRAN-based codes written for single CPU versions of finite-difference applications, was completed. The framework handles 2D and 3D applications of various kinds and is based on the BOXLib library, which works both for PC clusters and parallel supercomputers. The framework also provides support for heterogeneous workloads, par-

allel load-balance, and data distribution. It handles both center-based and staggered grid algorithms with cell-centered and grid node-centered parameter arrays. The effort was mainly dedicated to developing instructions and documentation.

## Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, ChevronTexaco, Conoco, Core Laboratories/Tomoseis, ExxonMobil, Fairfield Industries, Marathon, Mitchell Energy, Paradigm Geophysical, PGS-Tensor, Phillips, Shell, Society of Exploration Geophysicists [SEG], Unocal, Veritas DGC, Western Geophysical, Stanford, U of Houston, LANL, and LLNL)

### Highlights:

- Model for numerical simulation of elastic wave propagation nearly complete.
- Synthetic elastic seismic data computed for 120 shots over SEG salt model.
- Successful project meeting provides industry guidance.

One of the 2D models proposed for use in numerical simulations was adapted for use in elastic seismic simulations. The model was extended to twice its original size to allow longer source-receiver offsets. In addition, shear wave and density specifications derived from the original P-wave velocity specification were applied to the model. Layer properties were assigned with differing lithologies and fluid contents. Discussions about the modification of an existing 3D model continue.

Elastic simulations of a total of 120 shots from the Society of Exploration Geophysicists (SEG) salt structure were completed. Receivers consist of simulated Ocean Bottom Cables (4-C) and marine streamers (1-C). Three north-south and four east-west lines of shots were completed. Calculated traces are being reformatted to the SEG-Y standard format for posting on the project website.

A project meeting was held in Houston, TX, in January 2002, and drew attendees from 13 companies, including majors, independents, and service companies. Lively discussion provided important insights and guidance to the laboratory and university participants.

## Rapid Imaging of Interwell Fluid Saturations using Seismic and Multiphase Production Data

BP Amoco, ChevronTexaco, JNOC, Landmark, Phillips, RC2, Statoil, Tomoseis, Total-Fina-Elf, Texas A&M, and LBNL)

### Highlight:

- Method for relating cell saturation changes to reservoir model permeability changes developed.

As the first step in the computation of seismic attribute sensitivities to reservoir properties, project researchers developed a method for computing trajectories relating saturation changes in a cell to permeability changes in the reservoir model. The method utilizes output from a reservoir simulator and the saturation history to construct trajectories through the model. Sensitivities are defined along these trajectories. Work began on establishing a theoretical basis for these sensitivities, in tandem with the numerical computations. Project researchers are also extending the project's capabilities by considering cross-streamline processes in the modeling. Thus, researchers can incorporate processes such as transverse dispersion and capillary effects in the inversion.

Project researchers are gaining additional experience in the large-scale inversion of water-cut data. In particular, work is progressing on the inversion of a large suite of water-cut histories from a Middle-Eastern field.

**Innovative Wave-Equation Migration**

(Advanced Data Solutions, Amerada-Hess, Applied Geophysics Services, Baker Atlas, BHP, Conoco, Exxon-Mobil, Fairfield Industries, GX Technology, Petroleum GeoServices, Phillips, Screen Imaging, Shell, TomoSeis, Unocal, Veritas DGC, and LANL)

**Highlight:**

- Project meeting held in Houston, TX.

During the October 2001 project meeting held at Advanced Data Solutions (ADS) in Houston, TX, several industry participants were interested in a comparison of wave-equation migration images with those obtained using conventional ray-based Kirchhoff migration methods.

Project researchers performed migrations of several synthetic datasets using Kirchhoff migration with the finite-difference eikonal solver for ray tracing. The datasets investigated include poststack and prestack datasets for two 2D slices of the SEG/EAGE salt model and the prestack dataset for the Marmousi model. The results demonstrated that wave-equation migration images are remarkably superior to the Kirchhoff migration images for complex regions. Researchers are investigating the velocity sensitivity of the wave-equation migration methods and comparing it with that of the Kirchhoff migration. Researchers are also investigating the common-offset wave-equation migration.

**Testing and Validation of High-Resolution Fluid Imaging In Real Time**

(Deeplook, KMS Technologies, KJT Enterprises, LBNL, and SNL)

Agreements between LBNL, SNL, and industry participants were finalized. Work continues on the fiber-optic upgrade of the LBNL single well acquisition system. The system was tested in the lab, and a field test is scheduled for February 2002.

**Autonomous Monitoring of Production**

(Aera Energy, ChevronTexaco, SteamTech Environmental Services, TomoSeis, and LLNL)

The laboratory participants and industry participants met to discuss requirements for a field site in which much of the surface piping is metallic. Several possible sites in California were proposed, which would reduce travel costs to the project. Options for surface insulation were developed, depending on the field operations and piping configurations. Additional information is being gathered in order to plan field surveys to be conducted later this year. Improvements in both acquisition and interpretation were discussed.

## Partnership Office

The partnership completed the selection of projects and allocations of funds for FY02. Both the gas and oil programs at DOE/NETL have greatly assisted in a rapid turn-around of the funding proposals.

Now projects will receive funding earlier in the spring than in the past years. As a result, the new and continuing projects will make progress in advance of next year's review cycle.

Changes continue in the partnership. Charles Thomas

of INEEL, who led the Drilling Completion and Stimulation Technology area of the partnership for the last two years retired and moved to Alaska. We thank Charles for his efforts and good cheer. The partnership is looking under the lead of LBNL to develop new approaches to address the specific technology needs of NETL's gas program. One possible approach could be to establish a new technology area and review panel for gas technology. Stay tuned!